# 3 Beach macro litter

## 3.1 Introduction

Within the MSFD (Directive 2008/56/EC) and Commission Decision (EU) 2017/848, criterion D10C1 has been defined as 'The composition, amount and spatial distribution of litter on the coastline, in the surface layer of the water column, and on the seabed, are at levels that do not cause harm to the coastal and marine environment'. This criterion refers to items larger than 5 mm (macro litter and mesolitter). Moreover, the MSFD requires, when feasible, the collection of information on the sources and pathways of marine litter to pinpoint the prioritisation and elaboration of targeted prevention, reduction and mitigation measures. In addition to identifying tailor-made management approaches, the MSFD requires assessment of their effectiveness to feed into the decision-making process of the subsequent MSFD implementation cycles.

In September 2020, the Commission published a threshold value for marine macro litter (> 2.5 cm) on coastline, paving the way for reducing harm to European regional seas from beach litter to a sufficiently precautionary level. EU Member States' experts have agreed that the median value of beach litter within a country subregion has to be less than 20 items per 100 m of coastline to stay under the threshold as part of GES for marine litter (van Loon et al., 2020). The reduction of beach litter in Europe in order to move towards achieving GES requires a combination of efforts at different levels. These include legislative measures at the EU level, such as the European Plastics Strategy (European Commission, 2018), the Single-Use Plastics Directive ([11]), the Water and Waste policies, the Green Deal and the Circular Economy Action Plans; measures in the context of the European Regional Seas Conventions and Action Plans against marine litter; national initiatives ranging from the country level to the municipality levels, including awareness-raising targeting different societal actors.

### 3.1.2 Background and state of the art

Beach surveys for macro litter assessment are the most common marine litter monitoring (Ryan et al., 2009). Litter monitoring on the European Regional seas' coasts has developed from several community-based campaigns, mostly of NGOs (Galgani et al., 2013). Originally designed to heighten public awareness or make a simple assessment of the magnitude of the problem, they have developed over the past 40 years into a tool for monitoring litter washed ashore and/or deposited on beaches (e.g. Schulz et al., 2015). In 2013, the MSFD TG ML published operational guidelines on how to monitor beach macro litter on the European coastline to address the need for obtaining harmonised beach macro litter data and support Member States in setting up their beach macro litter monitoring programmes (Galgani et al., 2013). Indeed, the comparison of beach litter data among assessment programmes and Member State is one of the aims of the MSFD. While some Member State already have beach litter monitoring programmes in place (e.g. countries in the Helsinki Commission (HELCOM) region and those in the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) region; Schulz et al., 2013; HELCOM 2020), other countries only recently started to set up their marine litter monitoring programmes within the context of the MSFD (e.g. Italy; see Fortibuoni et al., 2021).

Most beach litter protocols that were used on European coasts during the first MSFD cycle focused on the collection and visual identification and classification of litter items found at shoreline sites. However, the protocols applied in some countries differed in terms of sampling units (type, size and positioning criteria), frequency and timing of the surveys, size limits for and classes of litter items to be surveyed, classification lists and quantification units (number, weight or volume of items per stretch of coastline or per surface area of coastline) (Hanke et al., 2019). The application of several protocols between and within European Regional seas made it difficult to compare data.

In 2017, within the TG ML and with the support of EMODnet, the first pan-European beach litter dataset for 2012-2016 was compiled and analysed to derive baselines for the MSFD (Hanke et al., 2019). The analysis involved data from 22 European countries and four marine regions. Data from 3063 surveys performed on 389 European beaches were considered. The biggest challenge faced during the data compilation phase was dealing with the heterogeneity of data formats, data quality and protocols used during the beach surveys. The outcomes of this analysis were considered in the revision of the beach macro litter monitoring guidance. One

([11]) Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment (OJ L 155, 12.6.2019, p. 1).

of the key findings was that five litter item classification lists were used, each featuring different levels of litter item category aggregations and total category numbers (Hanke et al., 2019). In response, the *Joint List of Litter Categories for Marine Macrolitter Monitoring* was prepared by the TG ML in close collaboration with Member States and the RSCs (Fleet et al., 2021). This list is based on a hierarchical system that facilitates the recording of litter items at different levels of detail. This enables the compatibility and comparability of results obtained through different marine litter recording schemes used for beach litter or those performed in other compartments of the marine environment (Fleet et al., 2021). The benefits of comparable data (also linked to the implementation of large-scale policy measures against litter) are evident. Indeed, in recent years, cooperation among the RSCs and the EU Member States led to a better harmonisation of data collected under different policy and legislative frameworks; a comparison of the latest versions of the different protocols (Table 3.1) shows an overall alignment of the most critical aspects, even if there is still room for improvement and additional efforts are needed. This chapter represents a further step towards harmonising the monitoring of litter on the coastline among Member States and the RSCs.

## 3.2 Scope

The TG ML has evaluated existing methods for monitoring litter on the coastline regarding their capacity to meet the MSFD requirements. The TG ML recommends a harmonised method that can be applied to assess beach litter in all European Regional seas, thus ensuring the consistency, compatibility, and comparability of monitoring data from coastal assessments of litter within and among regions. In this chapter, the methodology for conducting beach macro litter surveys within the MSFD is thoroughly described, and QA/QC aspects are addressed. In addition, an overview of other beach macro litter survey methods is presented.

## 3.3 Definitions and terminology

- Macro litter. Litter items larger than 25 mm in the longest dimension, with no set upper limit.
- Mesolitter. Litter items from 5 mm to 25 mm in the longest dimension.
- Microlitter. Litter items smaller than 5 mm in the longest dimension, with no set lower limit
- Monitoring campaign. The long-term process of carrying out one or more surveys in one or more survey sites with a certain frequency and within a given time period.
- Monitoring programme. A national or regional scheme for monitoring and assessing marine litter pollution.
- Monitoring protocol. A detailed description of the procedural method for monitoring marine litter pollution, including a reference list of litter types.
- Monitoring strategy. It outlines the survey sites and the associated survey sites selection criteria, the timing and frequency of the surveys, and the survey method.
- Sampling unit. A fixed section of coast covering the whole area from the water edge to the back of the beach (base of dunes, cliff, vegetation line or human artefacts), where the survey is carried out.
- Survey (or sampling). The process of recording data related to a sampling unit at a given time.
- Survey site (or sampling site). A beach or section of a large beach chosen for placing one or more sampling units.

Table 3.1. Comparison of the main aspects of the different beach macro litter monitoring protocols adopted by the MSFD TG ML (this guidance) and the RSCs (i.e. OSPAR, HELCOM, the Barcelona Convention and the BSC)

| | Litter size | Materials / main categories | List and item categories | Reporting unit | Survey frequency and timing | Sampling unit definition | Sampling unit length | Litter removal | Beach typologies | Selection of beaches (partial) |
|---|---|---|---|---|---|---|---|---|---|---|
| EU MSFD (1) | > 2.5 cm<br>Plus 15 categories of litter that are always recorded, even if < 2.5 cm | AP, R, C/T, P, WW, M, G/CE, CH, O, F | Joint list (Fleet 2021)<br>183 categories | Items/100 m | Four times a year | A fixed section of beach from the water's edge to the back of the beach (obstacles) | 100 m | Yes | Urban, semi-urban, remote/ natural | The beaches should be spatially stratified to reflect:<br>- different pressures and different levels of exposure;<br>– different development and urbanisation levels. |
| OSPAR (2) | > 5 mm ([a]) | AP, R, C, P, WW, M, G, CE, SW, MW | OSPAR list<br>126 categories | Items/100 m | Four times a year | A fixed section of beach from the water's edge to the back of the beach (obstacles) | 100 m | Yes | | The survey sites should be representative of the litter sources. The beaches should not be subject to any other litter collection activities. |
| HELCOM (3) | > 5 mm | AP, R, C/T, P, WW, M, G/CE, U | Different coding lists (Joint list, OSPAR (2010) or MARLIN (2013)) | Items/100 m | Three times a year | A fixed section of beach from the water's edge to the back of the beach (obstacles) | 100 m | Yes | Urban, semi-urban, remote/ natural | At least one beach is not included in the regular cleaning process and is frequented by few visitors. Beaches are preferably in rural areas. |
| Barcelona Convention (4) | > 5 mm | AP, R, C, P, WW, M, G, C, SW, MW, F, PW | IMAP list<br>131 categories: | Items/100 m and items/$m^2$ | At least two times a year | A fixed section of beach from the water's edge to the back of the beach (obstacles) | 100 m | Yes | Urban, peri-urban, rural | The beaches should not be subject to any other litter collection activities. |
| BSC | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

([a]) Only items > 2.5 cm are used for assessment.

NB: AP, artificial polymer materials; C, cloth; CE, ceramic; CH, chemicals; F, faeces; G, glass; IMAP, integrated monitoring and assessment programme of the Mediterranean Sea and coast and related assessment criteria; M, metal; MW, medical waste; U, undefined; n/a, not available; P, paper/cardboard; PW, paraffin/wax; O, organic food waste; R, rubber; SW, sanitary waste; T, textile; WW,

processed/worked wood. In dark green are the aspects that are fully harmonised; in light green are the aspects that are partially harmonised but still not fully in line; in orange are the aspects that have been addressed but would require additional effort to become harmonised.

*Sources:* (1) This guidance; (2) OSPAR Commission (2020); (3) HELCOM (2021); (4) UNEP/MAP (2019).

## 3.4 Marine Strategy Framework Directive methods for beach macro litter surveys

Capitalising upon the lessons learned from implementing the first MSFD cycle, the following protocol for carrying out beach macro litter monitoring has evolved.

### 3.4.1 Monitoring strategy

#### *3.4.1.1 Survey site selection*

Survey sites should, whenever possible, have the following characteristics:

- a minimum length of 100 m along the water edge (i.e. sufficient to have at least one sampling unit);
- composed of sand or gravel;
- low to moderate slope;
- clear access to the sea (not blocked by breakwaters or jetties);
- accessible to survey teams year-round.

Within the above constraints, the location of survey sites should be spatially stratified to reflect:

- different pressures and different levels of exposure to litter (e.g. close to river mouths, close to harbours/marinas, presence of touristic facilities nearby);
- different development and urbanisation levels, including a balanced mix of urban, semi-urban, and remote/natural beaches (Table 3.2 and Figure 3.1).

Table 3.2. Main characteristics of different beach typologies representing different levels of urbanisation.

| | Environment | Accessibility | Habitation and accommodation | Services and facilities |
|---|---|---|---|---|
| Urban | Located in front of urban areas, with a wide range of well-established public services (shopping areas, business districts, etc.) | Accessible by both public and private transport | Large population and large-scale residential and tourist accommodation | Extensively developed range of services and facilities provided for beach users |
| Semi-urban | Located in the surroundings of the urban areas, adjacent to or within a small coastal town with small-scale community services | Accessible by both public and private transport | Small residential populations and/or many beach users during the bathing season; presence of accommodation facilities (hotels, bed and breakfast, campsites) | A reduced range of services and facilities provided for beach users |
| Remote/natural | Remote and natural environment, located away from small towns or villages, a predominance of natural elements and absence of community services | Accessible by private transport, boat or walking; includes those beaches that are closed to the public | Absence of residential population, housing and tourist accommodations | Absence of services and facilities for beach users |

NB: The table is indicative, and some deviations may occur.

Figure 3.1. Examples of survey sites in Italy characterised by different level of development and urbanisation: (a) urban, (b) semi-urban and (c) remote/natural.

(a) (b) (c)

*Source:* Maps data – Google, ©2019.

The survey sites should be the same as those monitored in the first MSFD cycle to compare results over time. It is possible to replace one or more of the survey sites among those monitored until 2020, but only in the case of profound changes that make it impossible to monitor a site indefinitely (destruction of the coast, new positioning of breakwaters, inaccessibility, etc.). Changes should be kept to a minimum, and, where possible, the new monitored survey sites should have the same characteristics as the original ones. New survey sites can be established, by applying the selection criteria above, if this increases the representativeness of beaches at the country-region level. It is of utmost importance that the characteristics of their survey sites and any changes in the characteristics are recorded and saved for future reference (see below and Annex I – 'Survey site (beach) Identity Form (AI)').

There is no agreed statistical method for recommending a minimum number of survey sites represent a certain length of coast, a specific region or a country. It depends on the purpose of the monitoring, the geomorphology of the coast, the number of sites available that meet the criteria presented above, and trade-offs between available resources and monitoring needs. The sampling effort necessary to assess litter concentrations within a given region is, for instance, dependent on the desired level of detection (i.e. to detect small-scale spatial differences in litter quantity and composition, more sampling sites are required) and the heterogeneity of pressures.

It is proposed that beach litter surveys should be performed in at least four survey sites within a country-subregion (e.g. France – western Mediterranean Sea). This approach (four surveys per year in four survey sites) is in compliance with the method for assessing the threshold value for beach litter and would provide a sufficient number of surveys (over 40) within a 3-year period (van Loon et al., 2020).

It should be highlighted that all necessary precautions should be taken to ensure that surveys will not pose any threat to endangered or protected species such as sea turtles, shorebirds, marine mammals, or sensitive beach vegetation/habitats. In many cases, this could exclude protected areas from survey areas; however, this will depend on local management arrangements.

#### *3.4.1.2 Survey site metadata*

For each survey site, metadata on the characteristics of the site should be recorded and saved to facilitate the analysis and interpretation of results. Using the form provided in Annex I – 'Survey site (beach) identity form (AI)' is suggested. This form needs to be filled out once for each survey site and then updated if significant changes to the characteristics of the site occur (e.g. creation of a new residential area nearby).

The information that should be recorded for each survey site includes the following (see Annex I – 'Survey site (beach) identity form (AI)' for metrics and units):

- the total length of the coast/beach;
- the latitude and longitude of the central point of the beach (to identify the position of the beach);
- degree of urbanisation (urban, semi-urban, remote/natural);
- features related to the back of the beach (i.e. cliffs, dunes, rocks, forest, bush, crops, fields, built-up area, road, other);
- features related to the development behind the beach (e.g. camping, road, hotels);

- the main orientation of the coast/beach (i.e. the direction the coast is facing when looking from the coast to the sea);
- coastline curvature (i.e. linear, concave, convex or sinusoidal);
- beach substrate (i.e. percentage of sand, pebbles, rocky coast);
- objects in the sea that influence the currents (e.g. reefs);
- beach slope (i.e. level, gentle slope, moderate slope, steep slope);
- beach access (i.e. pedestrian, vehicle, only boat);
- beach usage (e.g. tourism and recreation, fishing) indicating for each usage if it is primary or secondary and whether it is seasonal or not;
- estimated number of people using the beach (seasonal average);
- any other relevant information (e.g. an incidental large-scale touristic event such as a surfing competition which may create a litter peak).

Some of this information can be obtained from maps and similar sources (e.g. Google Earth™ images), although this information should be checked by direct observation at the site. The collection of metadata would ideally be a task for a national or local coordinator of the beach litter surveys, who can access the required information and collect the information in a uniform way for all beaches.

#### *3.4.1.3 Survey frequency and timing*

Preferably four surveys per year should be carried out for each survey site. The proposed periods in which the surveys are to be performed are the following:

- winter – January
- spring – April
- summer – July
- autumn – October

These periods are more or less evenly distributed throughout the year. However, regional or even local conditions might prevent the performance of surveys in the periods proposed. Weather conditions (e.g. snow) in particular could prevent surveys in winter or spring. In addition, a high volume of tourists and extremely hot weather might hinder surveys in July. Surveys should not be undertaken during periods when there is a risk of affecting endangered or protected species, such as sea turtles and birds (i.e. nesting period).

While using harmonised monitoring periods among the countries is highly recommended, it is up to the national coordinators of beach litter surveys to choose the survey periods best suited for their regions.

#### *3.4.1.4 Sampling unit*

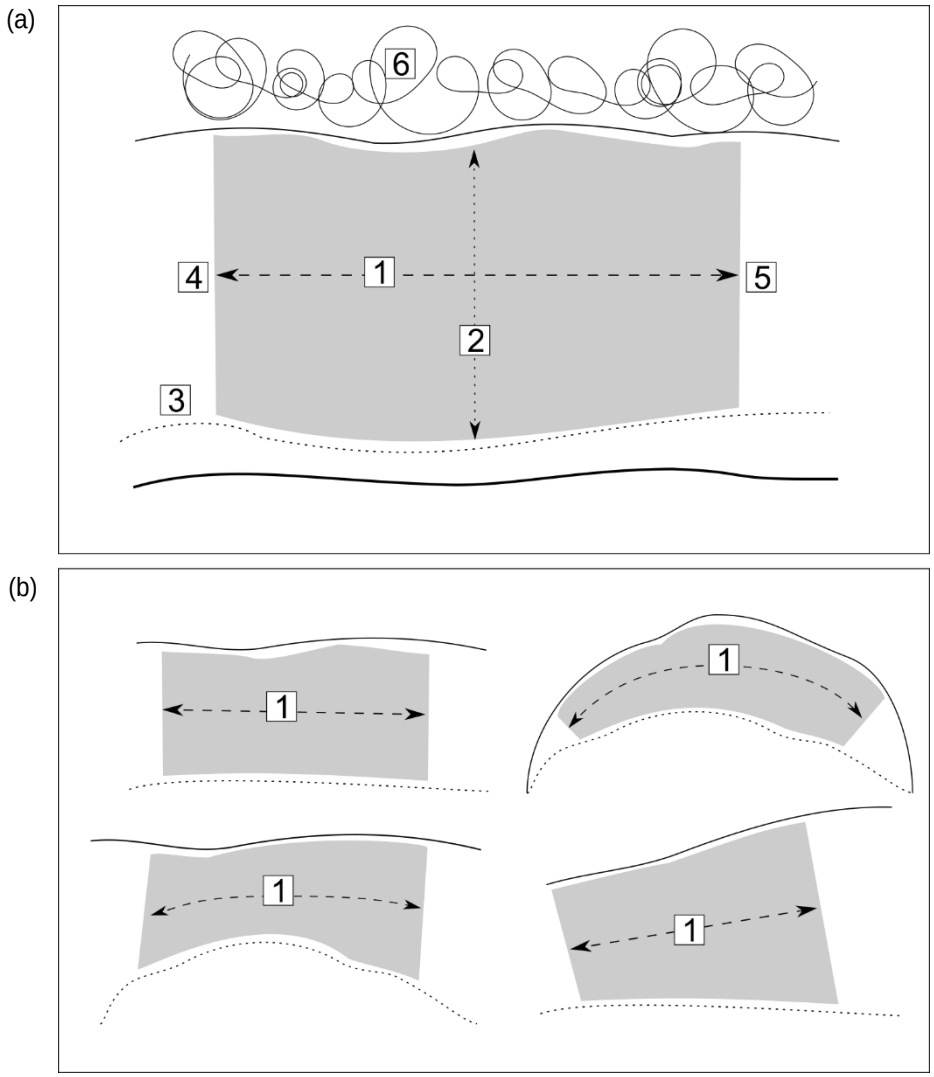
According to Commission Decision (EU) 2017/848, the unit of measurement for beach macro litter is the amount of litter per category in terms of number of items per 100 m of the coastline.

The sampling unit is a stretch of coast of 100 m in length covering the area from the water's edge to the back of the beach measured at half the actual width as a curved line on curved beaches or a straight line on straight beaches. Examples of how to measure the length of the sampling units are provided in Figure 3.2(b). Please note that, if the monitored stretch deviates slightly from the suggested 100 m length, the results must be normalised to 100 m when reported.

Sampling units should represent the general characteristics of the survey site and the overall state of litter within it. The sampling units should not be placed on the edges of a beach or on parts of the beach that have a higher likelihood of accumulating litter. In addition, the sampling unit should not be placed in potential litter hotspots, such as areas near the entrance of the beach, near coastal parking lots or directly in front of hotels. Based on these considerations, a set of potential sampling units should be identified and a random selection of survey units should then be made from this set (e.g. dividing the coast into 100 m sections and randomly choosing a number of these sections as sampling units) (Figure 3.3). However, existing sampling units from

long-running monitoring programmes (e.g. those used for the first MSFD monitoring cycle) should continue to be surveyed.

Figure 3.2. (a) Sampling unit characteristics and (b) suggested method to measure the length of the sampling unit in differently shaped beaches



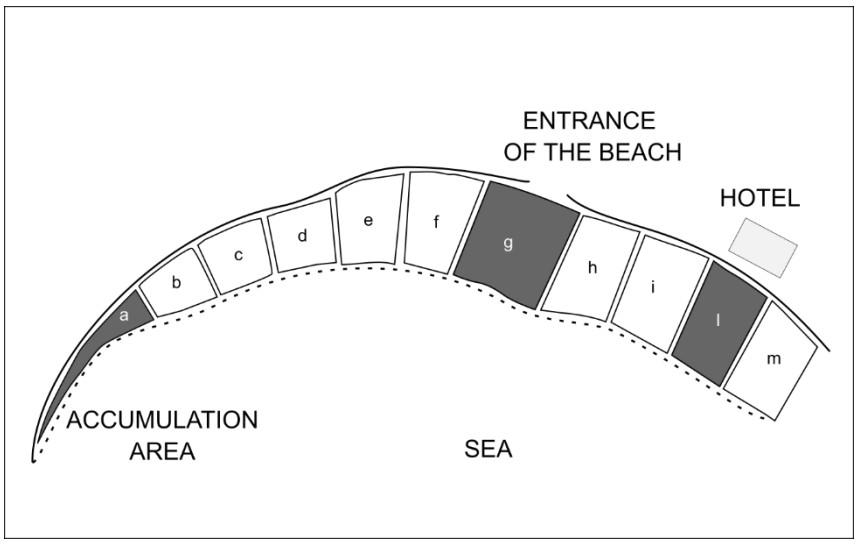

NB: Numbers refer to the following: 1, sampling unit length; 2, sampling unit width; 3, edge of the water; 4 and 5, GPS coordinates of the sampling unit; and 6, back of the beach.

*Source:* Created by the authors.

In heavily littered survey sites (i.e. where a 100 m stretch requires more than 1 day of work to be surveyed) (Figure 3.4), a smaller sampling unit (at least a 50 m stretch of coast covering the area from the water's edge to the back of the beach), representative of the situation, can be monitored. Note that the results must be normalised to 100 m when reported to obtain comparable results.

Monitoring more than one sampling unit at the same survey site allows an estimation of the sample variability (e.g. the sample mean and standard error).

Figure 3.3. Example of how to select the sampling unit(s): once potential hotspots (shaded sections: a, g and l) are excluded, the sampling unit(s) should be chosen randomly from the remaining 100 m sections of the beach (unshaded sections b, c, d, e, f, h, i and m)




*Source:* Created by the authors.

Figure 3.4. Examples of heavily littered sites.

(a) (b)

*Sources:* Photo credits – (a) Vlachogianni, T., and (b) Fortibuoni, T.

### *3.4.1.5 Sampling unit metadata*

The same sampling units should be monitored for all surveys planned in the monitoring programme. The sampling units' coordinates should be documented (sampling unit start latitude/longitude and sampling unit end latitude/longitude) (see Figure 3.2(a)). If absolutely necessary (e.g. because of the construction of a tourist facility), the sampling units can be replaced with new units within the same stretch of coast. In such cases, new metadata must be recorded. As beach litter distribution is usually heterogenic, even on a small scale, the replacement sampling unit must be very close to the original one. Coordinates obtained by GPS are useful for identifying the sampling units; easily identifiable landmarks can be used, provided that their presence and position are consistently maintained over time.

The following information can be collated once for each sampling unit (using the form provided in Annex II – 'Sampling unit identity form (A2)' is suggested) and, once recorded in a database, can be used for all future surveys:

- the sampling unit length, measured along the beach curve at the mid-point between the water's edge and the back of the beach (see Figures 3.2 and 3.5);
- the sampling unit width (perpendicular to the shoreline line), defined as the distance between the water edge and the back of the beach (base of dunes, cliff, vegetation line or human artefacts) and measured at half its length – beach width should be measured at the mean water level in areas with small tidal amplitudes and at the mean high tide level for areas with high tidal amplitude (see Figures 3.2(a) and 3.5);
- start/end GPS coordinates;
- direction of the prevailing winds;
- direction of the prevailing water currents;
- name, distance to and position of the nearest town, and the size its residential population;
- distance to and position of the nearest food/drink outlet and the months in which the food/drink outlets are present;
- name, distance to and position of the nearest harbour and the type of shipping using the harbour (e.g. passenger, merchant, fishing, military, recreational);
- name, distance to and position of the nearest river mouth;
- distance to and position of the nearest wastewater or stormwater discharge point;
- distance to and position of the nearest shipping lane and the type and intensity of marine traffic.

Much of this information can be obtained from maps and similar sources (e.g. Google Earth™ images), although this information should be checked by direct observation at the site.

Figure 3.5. Examples of sampling units starting from the water's edge and extending to the back of the beach

(a)

(b)

NB: In part (a), the back of the beach is defined by the presence of trees and vegetation; in part (b), it is defined by the dunes.

*Sources:* Photo credits – (a) T. Vlachogianni and (b) T. Fortibuoni.

## 3.4.2 Survey protocol

### *3.4.2.1 Survey metadata*

For each survey performed on a sampling unit, the following data should be recorded (using the form provided in Annex III – 'Marine litter monitoring survey form (A3)' is suggested):

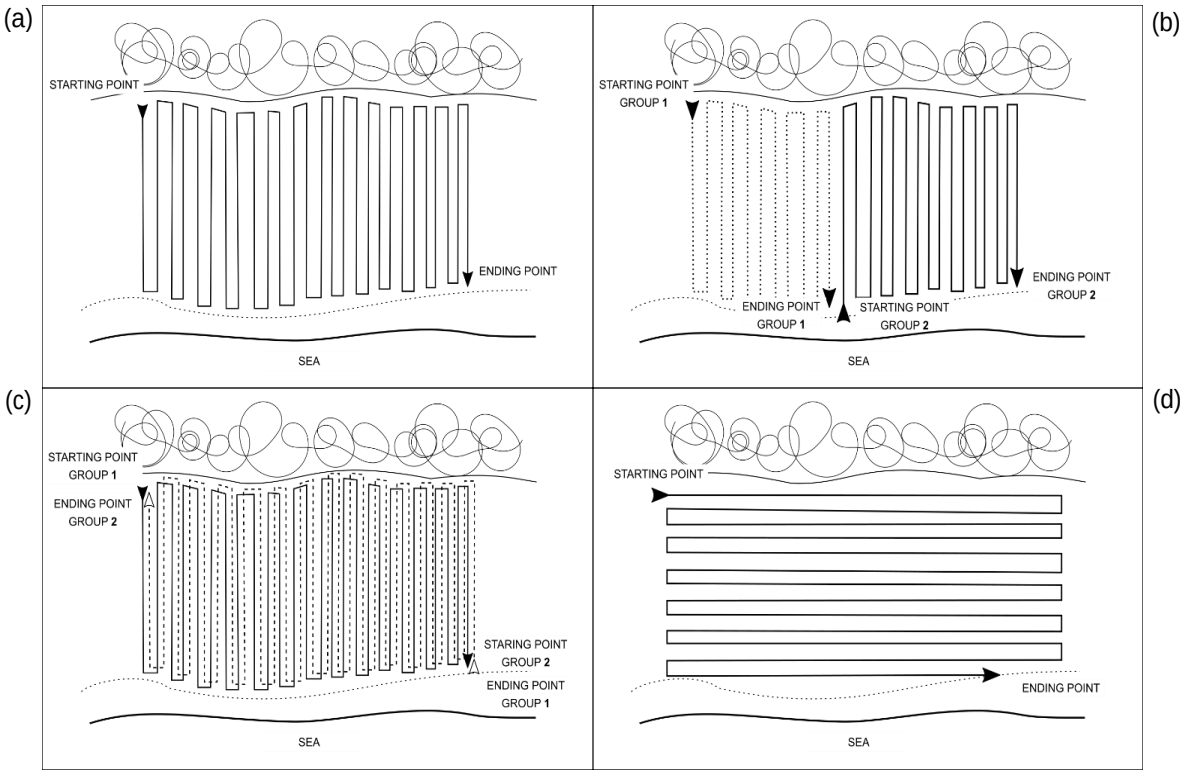
- sampling unit code/name;
- survey date;

- surveyors' names and contact details;
- length of the surveyed sampling unit, which may differ slightly from the suggested 100 m, measured along the beach curve at the midpoint between the water's edge and the back of the beach (see Figures 3.2(b) and 3.5);
- date of the last known cleaning action (e.g. municipality beach cleaning, clean-up days);
- weather conditions during the dates of the surveys;
- any deviation from the sampling protocol (e.g. transect length reduction or displacement of the transect, sampling outside the expected period, subsampling) and motivation (e.g. extreme weather events, flooding, new infrastructures in place);
- special circumstances and events that could have caused unusual litter in terms of abundance and/or type (e.g. clean-up actions, mechanical cleaning, beach party or competition, cargo losses nearby, extreme weather conditions);
- information on any entangled fauna encountered during the survey (details of the organism, nature of entanglement, live or dead).

#### *3.4.2.2 Litter sampling*

To ensure that all macro litter items are recorded in the sampling unit, a systematic sampling approach should be deployed. Some examples are shown in Figure 3.6. All items found on the surface of the sampling unit must be recorded (litter items should not be dug up). Items entangled in seaweed or other natural materials should also be considered.

Figure 3.6. Examples of litter sampling approaches. (a) recommended path, transverse to the water's edge, (b) different groups of surveyors can monitor different sections of the transect at the same time, (c) different groups of surveyors monitoring the whole section but in opposite directions and (d) path parallel to the water's edge




*Source:* Created by the authors.

#### *3.4.2.3 Litter size ranges and classification*

A lower limit of 2.5 cm in the longest dimension is set for macro litter items monitored during beach surveys. However, the specific objects listed in Table 3.3 should be recorded in all cases, even if they measure less than 2.5 cm. An upper size limit has not been established.

Table 3.3. Items from the Joint List that should be recorded during the macro litter surveys even if smaller than 2.5 cm in the longest dimension

| Code | Name |
|---|---|
| J182 | Metal fisheries-related weights/sinkers, and lures |
| J178 | Metal bottle caps, lids and pull tabs from cans |
| J195 | Metal household batteries |
| J21 | Plastic caps/lids drinks |
| J100 | Plastic medical/pharmaceuticals containers/tubes/packaging |
| J22 | Plastic caps/lids chemicals, detergents (non-food) |
| J23 | Plastic caps/lids unidentified |
| J24 | Plastic rings from bottle caps/lids |
| J91 | Plastic biomass holder from sewage treatment plants and aquaculture |
| J32 | Plastic toys and party poppers |
| J60 | Plastic fishing light sticks / fishing glow sticks including packaging |
| J257 | Foamed plastic packaging |
| J27 | Tobacco products with filters (cigarette butts with filters) |
| J131 | Rubber band (small, for kitchen/household/post use) |
| J125 | Rubber balloons |

*Source:* Adapted from Fleet et al. (2021).

The MSFD TG ML *Joint List of Litter Categories for Marine Macrolitter Monitoring* (Fleet et al., 2021) should be used for classifying the litter items sampled. Using the most detailed level of the joint list is highly recommended. The manual for applying the Joint List classification system provides detailed information on how to classify litter items (Fleet et al., 2021).

Litter items can be classified and recorded either on-site or in a sheltered place (e.g. a lab) after the sampling has been completed (e.g. in the case of bad weather conditions and/or heavily littered beaches); however, the latter approach should be avoided for weathered or fragile items, which can easily disintegrate, potentially leading to an overestimation of these litter items.

For specific purposes, it may be worth recording additional data regarding litter items (Cau et al., 2019), for example:

- the expiry date and/or the production date reported on food packaging or other containers;
- the geographical origin of the item if the label or the barcode is readable;
- whether it is deposited *in situ* or whether it was washed out from the sea;
- weight per material category (i.e. chemicals, clothes/textile, food waste (organic), glass/ceramics, artificial polymers/plastic, paper/cardboard, rubber, processed/worked wood);
- the size of litter items, since this can provide a link to litter quantities (the manual for the application of the *Joint List of Litter Categories for Marine Macrolitter Monitoring* (Fleet et al., 2021) provides recommended approaches to recording the size of objects).

#### *3.4.2.4 Litter removal*

All items sampled during the survey must be removed from the sampling unit. The litter collected should be disposed of properly. Local, regional or national regulations and arrangements for waste disposal should be followed. Larger items that cannot be removed (safely) by the surveyors should be marked, for example, with paint spray (that meets environmentally friendly standards) so that they are not counted again in the next surveys.

#### *3.4.2.5 Survey equipment and consumables*

The following equipment and consumables are recommended when carrying out the surveys:

- a hand-held GPS unit (with extra batteries);
- a measuring wheel or a 100 m decametre;
- flag markers/stakes;
- a sturdy 30 cm ruler;
- a clipboard and field sheets (one per team) and/or a mobile phone or a tablet for recording litter items;
- pencils and rubbers;
- printed list of items (the Joint List codes and names are recommended);
- high-resolution cameras (e.g. digital single-lens reflex cameras (DSLR), mirrorless, smartphones);
- protective gloves;
- bags to collect the litter (mesh bags can be used for bigger items);
- a rigid container and sealable lid to collect sharp items such as needles;
- a first aid kit.

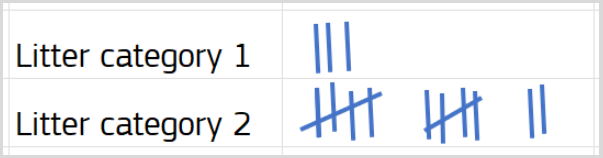
Box 3.1 provides practical tips on conducting surveys and Box 3.2 lists safety considerations.

Box 3.1. Practical tips on monitoring beach macro litter

Print the field form from Annex III – 'Marine litter monitoring survey form (A3)'. This will ensure harmonisation.

Items that easily break or get entangled and are weathered must be sorted and classified on-site to avoid errors.

To record the items one by one, a quick method is to use slashes marks on the litter items recording sheet: in the example, this approach makes it convenient to count items in groups of five at the conclusion of the survey.




To speed up the survey, the items can first be grouped into categories according to the Joint List and then counted together

Arranging the litter types on the field list according to the most frequent items found can facilitate the recording of the litter items found.

To ensure that the sampling unit's entire area is sampled and no parts are left out, small flags moved along the beach during the survey can be used to mark subsections.

Field forms should be entered into a database or digital storage medium (e.g. a spreadsheet) within 3-days of the field surveys. This will ensure a good recollection of the litter observations and field conditions.

A tablet or smartphone with access to the European Commission's European Commission's 'Online photo catalogue of the joint list of litter categories' web could help the categorisation of the items. Unusual or not recognisable litter items can be photographed for further evaluation.

Box 3.2. Safety considerations

Safety should be the number one priority during any survey activity. Since this work is carried out in the field, there are a few inherent hazards. Caution should be used, and the general safety guidelines presented below should be followed.

Start the monitoring about 1 hour after high tide to prevent surveyors from being cut off by the incoming tide.

Check and avoid circumstances that may lead to unsafe situations for surveyors: heavy winds, slippery rocks and hazards such as rain, snow or ice.

Wear appropriate clothing (sturdy shoes and gloves) when handling litter, as they may have sharp edges. If you come across a potentially hazardous material (e.g. oil or chemical drums, gas cans, propane tanks), contact competent authorities to report the item. Do not touch or sniff the material or attempt to move it.

Large, heavy objects should be left in place. Do not attempt to lift heavy litter items; instead, report them to the appropriate authorities for removal.

When in doubt, do not pick it up! If the item is potentially hazardous (e.g. ammunition), report it to the appropriate authorities.

Be aware of your surroundings and be mindful of trip and fall hazards.

Always carry a first aid kit. The kit should include an emergency water supply, sunscreen and bug spray.

Understand the symptoms of heat or cold stress and the actions to treat them.

Make sure to carry enough water.

Carry a means of communication for emergencies, for example, a mobile phone.

Let someone know where you are and when you expect to return.

## 3.5 Quality assurance / quality control

Implementation of consistent QA/QC practices should be considered early and throughout the beach macro litter monitoring process, including the monitoring strategy design, the sampling and classification, the data processing and reporting. Although there are many facets to QA/QC, the most important elements when surveying macro litter are related to the survey sites' locations and their respective number, the timing of surveys, the positioning of the sampling unit on the survey site, the collection and classification of litter items, the data control and reporting and the metadata documentation.

### 3.5.1 General quality assurance / quality control measures

Establishment of a beach macro litter monitoring organogram. It is recommended that the Member States establish an organisational chart with clear-cut and distinct roles for each type of staff (including third parties, NGOs) involved in the design and implementation of the beach macro litter monitoring strategy. Some proposed roles include national coordinators, local coordinators, fieldworkers/surveyors, and data managers with one or more of the following QA/QC related roles. These roles can include:

- establishment of a national macro litter monitoring strategy;
- selection of survey sites in compliance with this guidance;

- training, coordination, and supervision of field workers;
- collection and recording of data and metadata related to the survey sites, the sampling unit and the survey;
- establishment of contact with local municipalities and local NGOs to better plan the surveys and obtain the latest information on beach-cleaning activities;
- performance of quality control for the monitoring data (checking the correctness of the data directly before and after their entry into a database and undertaking an annual quality control examination of national beach macro litter data);
- management of the national macro litter monitoring dataset, including all related data and metadata.

Establishment of an advanced training programme. High-quality training is essential to ensure data quality, and it needs to include the development of operational (field) skills. It is recommended that the surveyors are engaged on a long-term basis to maintain experience and knowledge of how the monitoring should be performed. Member States should provide adequate training for the fieldworkers who participate in the surveys. Staff and/or volunteer training programmes should also incorporate information on the results and outcomes of the beach macro litter surveys so that field workers can understand the context of the macro litter assessment programme. In addition, the training programme should include hands-on calibration exercises to ensure, among other aspects, that macro litter items are attributed correctly to the litter types included in the field protocols. Inter-calibration exercises with neighbouring countries and at the regional sea level could be carried out if necessary.

### 3.5.2 Quality assurance / quality control measures related to sampling

When performing the beach macro litter sampling, the following best practice measures are recommended to reduce biases and/or errors.

Sampling design. Identifying appropriate survey sites (sampling site) types and numbers is paramount for establishing a comprehensive macro litter monitoring programme. Survey sites should be identified by using a stratified randomised approach. An initial pool of survey sites should be identified with locations that reflect different human-induced pressures leading to different litter densities and compositions. From this pool of locations, the actual sites should be selected randomly, considering the characteristics mentioned in Section 3.5.1. A sufficient number of survey sites should be chosen considering the coastline length of a country and the diversification of pressures (in terms of intensity or typology).

Sampling unit. To ensure that the sampling unit reflects the overall beach status, it should be positioned in the most representative section of the beach. This means that the parts of the beach where litter might tend to accumulate should be avoided and the sampling units should be located at least 50 m from points of access to the beach. In addition, special attention should be given to surveying exactly the same sampling unit in each seasonal survey and keeping to precisely the same 100 m stretches of the beach during each survey. If a sampling unit has to be moved for some reason (e.g. erosion of the coastline), it must be defined as a new sampling unit.

Representative sampling. Beach macro litter sampling is influenced by many factors, such as extreme weather phenomena and clean-up operations. It is recommended that the beach macro litter survey be postponed to at least 14-days after a weather-related or clean-up-related event that may have affected the abundance of macro litter on the beach. In addition, sampling units could be explicitly marked as national monitoring areas (e.g. by putting signs on the coastline) to discourage people from removing litter from that site. Moreover, a national database could be set up to register all coastal clean-up activities.

Replicate surveys. To increase the accuracy and precision of beach macro litter data from beach surveys, replicate surveys in close proximity to the sampling unit can be conducted. Average values can then be used for assessments. For research purposes, the individual replicate survey data can be stored separately.

### 3.5.3 Quality assurance / quality control measures related to sample processing

The sample processing elements of a beach macro litter survey address the litter items' removal, sorting and classification. The following best practice measures are recommended.

Litter item collection. All the litter items found (without digging) on the beach within the boundaries of the sampling unit must be collected. Litter items that easily break or get entangled and/or are weathered must be classified on-site to avoid the introduction of errors in their numbers due to fragmentation or entanglement during transport and processing.

Litter items sorting and classification. All macro litter items collected should be classified according to the categories of the Joint List of macro litter items. The photo guide can help the surveyors identify and categorise the litter items ([12]). Pieces of litter that are recognisable (e.g. a piece of a drinking bottle) should be registered as such (see also Fleet et al., 2021). Unusual or unknown litter items or recognisable litter items, that are not attributable to litter types from the field protocol, should be recorded along with a description and a photograph. In this way, emerging litter types can be identified and considered for inclusion updates/revisions of the protocol. It is recommended that the most experienced members of the surveying team supervise the final classification of the litter items.

### 3.5.4 Quality assurance / quality control measures related to data processing and reporting

All data and metadata should be reported using a 'standardised' data reporting sheet. The local coordinator should undertake the data collation and data quality assurance for each survey. Once submitted to the national database, the data should undergo additional control by the national data manager. The national coordinator will undertake responsibility for the review and final approval of uploaded data and will clarify any issues with local coordinators. Annual checklist documentation will provide an incentive for national coordinators, at the end of the monitoring year, to check that all surveys have been carried out and that all relevant information has been collected and entered into the appropriate beach litter database. This would ensure a high level of consistency within each region and create a hierarchy of quality assurance on data acquisition. The use of such a system will also support a comprehensive analysis of the data providing the opportunity to undertake statistically robust comparisons over time and between survey locations (Cheshire et al., 2009). Relevant databases that serve the needs of the Member States are made available by EMODnet (https://www.emodnet-chemistry.eu/marinelitter) for European Regional Seas, and by the OSPAR Commission for the north-east Atlantic Ocean (http://beachlitter.ospar.org).

## 3.6 Costs and efforts needed for beach monitoring

Compared with the methods described in this guidance for other compartments, beach litter monitoring is far less burdensome in terms of efforts and costs. In most cases, the survey sites can be easily reached by car and on foot. The operators need a low/medium level of expertise to collect and categorise the items, as long as expert supervisors train the participants and perform accurate quality control during and after the collection, especially regarding the marine litter item subcategories. The equipment required to perform the beach surveys is mainly related to the safety of the operators, while, for the actual collection and classification of the items, the expenses are low (see Section 3.4.2.5). The time required for collecting the items may vary greatly depending on the state of the beach and, thus, the quantity of litter accumulated. In general terms, 1-day may be sufficient to monitor one survey site (100 m length), including the collection, characterisation and disposal of the items. The relatively simple and easy-to-apply protocol for coastlines allows several Member States to involve NGOs and citizen science projects, which may drastically increase the cost-effectiveness of beach monitoring programmes under the MSFD. Beach litter data can be analysed with basic statistical methods and software, at least for a general overview and reporting purposes.

## 3.7 Other beach macro litter monitoring methodologies – an overview

In addition to the beach macro litter monitoring method described in this guidance, which provides data for the MSFD reporting requirements, several other methods are used to perform beach macro litter surveys, with different aims. The data from these surveys could potentially be compared with the MSFD monitoring data by using the *Joint List of Litter Categories for Marine Macrolitter Monitoring*. While it is not possible to specify a best method in general, it should be kept in mind that it is important to adopt the most appropriate monitoring methodology taking into account the aims of the study, the characteristics of the sites monitored,

([12]) See European Commission (undated), 'Online photo catalogue of the Joint List of Litter Categories': (https://mcc.jrc.ec.europa.eu/main/photocatalogue.py?N=41&O=457&cat=all).

the staff involved and other specific aspects of the survey. It is also important to acknowledge that each methodology has its pros and cons and strengths and limitations that need to be considered when analysing and interpreting the data (Velander and Mocogni, 1999).

Beach macro litter studies are commonly categorised into two main types: accumulation and standing stock studies (Ryan et al., 2009). Accumulation studies require the initial removal of all litter from the site, followed by regular surveys to record and remove all litter. The data collected over time may provide an estimate of the litter's flux on the shoreline (e.g. Prevenios et al., 2018). To have a realistic estimate of loading rates (fluxes), a high frequency of sampling is needed, which may pose substantial challenges in terms of high time costs (Smith and Markic, 2013). Conversely, carrying out surveys four times a year, as suggested in this guidance, allows the assessment of long-term balance between input and output (standing stock). In contrast, surveys that are run more frequently provide information on what is arriving over a shorter time frame (GESAMP, 2019).

### 3.7.1 Rapid surveys

Rapid surveys for beach litter (i.e. surveys that can be completed in a short time and are not based on a detailed assessment of litter types) may be used to provide an initial 'snapshot' of the distribution and abundance of marine litter. They can be useful in the case of a major natural disaster (e.g. a tsunami or typhoon); to collect a qualitative or semi-quantitative estimate of litter abundance and composition that is sufficient to direct further recovery operations or monitoring design; to provide a baseline to inform the development of a routine monitoring programme; and to identify accumulation hot spots for possible intervention. This kind of survey is not intended for application where detailed information about litter amounts, composition and fluxes is required.

For instance, in the frameworks of the Interreg Mediterranean Actions for Marine Protected Areas project (AMARE) (https://amare.interreg-med.eu) and the Interreg Mediterranean Plastic Busters Marine Protected Areas (https://plasticbustersmpas.interreg-med.eu) project, rapid surveys for beach litter were performed with small boats (5-6 m) operating at low speed (1-12 knots) from 20 m to 100 m from the shore along the coast of Corsica (France). The presence of litter was recorded for low accumulation zones (2-10 litter items per site, which were usually a 5-30 m apart) and high accumulation zones (> 10 litter items per site). The position of accumulation areas was recorded using GPS. A detailed assessment of litter types was not performed.

The development of image capture using aerial photography has proved to be useful for rapid assessments of litter, allowing large-scale coverage (GESAMP, 2019). These methods and their limitations are described in the subsequent sections.

### 3.7.2 Imaging techniques

Imaging techniques are particularly useful for detecting litter in dense vegetation (e.g. reed beds), and for non-destructive observations in sensitive habitats (e.g. salt marshes) and remote or inaccessible coastlines. Indeed, distant and rugged coastline segments are usually challenging to monitor conventionally. A variety of remote, aerial monitoring methods have been implemented, using fixed-wing aircraft (Kataoka et al., 2018), bush planes (Moy et al., 2018), balloons (Nakashima et al., 2011), aerial vehicles (Papakonstantinou et al., 2016; Deidun et al., 2018; Martin et al., 2018) and webcams (Kako et al., 2018; Kataoka et al., 2018).

Unmanned aerial vehicles (UAVs) / unmanned aircraft systems (UASs) (e.g. drones) may be good technological options for beach macro litter monitoring (e.g. Martin et al., 2018; Papakonstantinou et al., 2021). Their use has the advantages of high image acquisition frequency, high spatial resolution, the ability to fly at low altitudes below clouds, and high mobility (Bao et al., 2018). UAVs/UASs can be used to acquire georeferenced red, green and blue (RGB) images along the coastline cost-effectively and rapidly (Deidun et al., 2018). A post-processing system based on visual interpretation of the images allows the localisation and identification of the marine litter within the scanned area and the estimation of its spatial and temporal distribution (Merlino et al., 2020). Deep learning algorithms can automatically identify and quantify marine litter (Fallati et al., 2019). However, it has been shown that monitoring with UAVs/UASs may lead to an underestimation of beach litter compared with human inspection since, for instance, hidden and transparent items cannot be detected (Merlino et al., 2020). Another limitation of using UAVs/UASs is adverse weather conditions because surveys cannot be carried out on windy or rainy days.

Another method that could be used for inaccessible beaches is based on the acquisition of high-resolution images through vessel-based photography surveys (Papachristopoulou et al., 2020) or by applying image processing techniques to archived shoreline aerial photographs (Kataoka et al., 2018). Vessel-based

photography provides a good trade-off between high-quality photographic documentation, spatial coverage, processing time, and operational cost. At the same time, unlike other remote methods, it could easily be performed by non-experts (Papachristopoulou et al., 2020). However, it is worth noting that the quantification of beach litter abundance through remote photography may result in an underestimation of litter densities when the quality and resolution of the images are poor, for instance, as a consequence of bad illumination due to bad weather or it being impossible to navigate close to the coast.

### 3.7.3 Participatory science and community-based initiatives

Even though there is no internationally accepted definition of citizen science, the term mainly refers to the involvement of non-professional volunteers, typically in data collection, but also in other phases of the scientific process, such as data interpretation, problem definition or the dissemination of results (Bonney et al., 2009; Haklay, 2015).

Participatory science is a more inclusive term that refers to 'research conducted in partnership between trained experts and members of a "community" or CSOs [civil society organisations]', including non-governmental organisations (NGOs) (Gall et al., 2009, p. 12). Throughout the years, NGOs have significantly contributed to providing data and information on the temporal and spatial distribution of marine litter found stranded on beaches, and participatory science campaigns have proved to be an essential tool to fill in the marine litter knowledge gaps (Hidalgo-Ruz and Thiel, 2015). In many cases, environmental NGOs can produce fit-for-purpose and accurate beach litter monitoring data for institutional purposes (Vlachogianni et al., 2020).

#### *3.7.3.1 Clean-up and removal*

Community-based beach litter initiatives mainly focus on clean-up and removal actions (e.g. Ocean Conservancy's International Coastal Cleanup, NOAA Marine Debris Program, Clean Up the Med campaign, SeaCleaner) rather than research/monitoring actions. These actions may generate estimates of litter amounts at a particular site. Community-based projects that focus on research and monitoring (citizen science) can produce good-quality data on litter (e.g. van Der Velde et al., 2017; Vincent et al., 2017; Chen et al., 2020; Haarr et al., 2020; Kideys and Aydin, 2020; Vlachogianni and Scoullos, 2023), provided that volunteers are trained, and professionals/scientists supervise and guide them. A rigorous citizen science programme requires intensive coordination and communication with the volunteer participants. The resulting data must be controlled, reviewed and validated by experts to remove mistakes and spot unlikely results that are from errors or misunderstandings in data acquisition (GESAMP, 2019). The general public's involvement in research can generate added value in addition to producing new data; for example, it can raise awareness, strengthen custodianship for the local environment and increase pressure on policymakers to act (Merlino et al., 2015; GESAMP, 2019).

#### *3.7.3.2 Hotspot surveys*

While the MSFD coastline litter surveys are based on the repeated monitoring of a fixed set of beaches, litter quantification on other beaches may provide important complementary information and help to identify litter hotspots that might require special attention, potentially reducing litter input to the marine environment, for example, through specific local measures. Such surveys would ideally use the same protocols as the MSFD surveys and thus enable a comparison of data.

#### *3.7.3.3 Rare events monitoring and early warning*

Opportunistic beach litter surveys involving citizens can provide a cost-effective approach to documenting relatively rare events such as animals' entanglement in litter or to following the spread of massive quantities of litter items along the coastline due to unexpected events, such as a cargo loss or an accident along the coastline. This type of survey is based on massive amounts of citizens' engagement, resulting in the broader distribution of the observations in space and time and an early warning system. Dedicated websites and/or apps can facilitate the collection of this data (e.g. https://seawatcher.info-rac.org).

#### *3.7.3.4 The EEA Marine Litter Watch*

The EEA has developed the Marine Litter Watch to strengthen Europe's knowledge base and thus provide support to European policy implementation. MLW offers tools – an app ([13]) and a public database ([14]) - to collect and share data on marine litter on beaches. A web portal ([15]) is also available for the communities to manage their events and data. Communities organise events on beaches and make surveys with the Marine Litter Watch app to report on litter items found.

## 3.8 Resources

When recording and analysing litter on the coastline, Member States and other communities can benefit from the set of tools and resources developed in the last decade to collect, store, visualise and analyse data.

EMODnet. EMODnet is a European initiative funded by the Directorate-General for Maritime Affairs and Fisheries. The initiative is divided into seven thematic areas, each focused on a specific topic. EMODnet Chemistry (https://emodnet.ec.europa.eu/en/chemistry) started in 2009, intending to support the MSFD implementation with a data management plan (Molina-Jack et al., 2019). Marine litter was included among the target parameters in 2017. In recent years, a joint task has been performed to develop a standard data structure for marine litter at the European level. It was modelled to host MSFD monitoring data, following the OSPAR beach litter database (OSPAR-MCS) approach and taking into account the MSFD TG ML and UNEP / Mediterranean Action Plan requirements (Molina-Jack et al., 2019). The collaborative action between the JRC, the TG ML, and EMODnet Chemistry for gathering official MSFD monitoring data for calculating European baselines and thresholds gave the database an initial boost, including a large number of datasets in 2018 (Partescano et al. 2021).

LitteR. LitteR (Schulz et al., 2019) is an open-source statistic tool for analysing litter data developed as an R package (R Core Team, 2021), to support OSPAR and EU scientists and policymakers. This package offers a simple user interface for analysing litter data in a consistent and reproducible way. It contains routines for data quality control, outlier analysis, descriptive statistics, trend analysis and regional aggregation of states and trends. The tool produces a detailed analysis report in HTML format, from which tables and figures can be copied (https://cran.r-project.org/web/packages/litteR/). Schulz et al. (2017, 2019) provide more background information on the statistical data analysis of beach litter.

([13]) See EEA (undated-a), 'Marine Litter Watch', https://marinelitterwatch.discomap.eea.europa.eu/Index.html
([14]) See EEA (undated-b), 'Marine Litter Watch data viewer', https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/marine-litterwatch/data-and-results/marine-litterwatch-data-viewer/marine-litterwatch-data-viewer
([15]) See EEA (undated-a), 'Marine Litter Watch', https://marinelitterwatch.discomap.eea.europa.eu/Index.html